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### COMPLETE SPECIFICATION

## Improvements in and relating to Electric Discharge Devices of the Low Pressure Positive Column Type

We, THE BRITISH THOMSON-HOUSTON COMPANY LIMITED, a British Company having its registered office at Crown House, Aldwych, London, W.C.2, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement :—

Our invention relates to electric discharge devices of the low pressure positive column type, such as fluorescent lamps and low pressure positive column discharge devices for producing ultraviolet radiation.

It is an object of our invention to provide new and improved low pressure positive column electric discharge devices, a circuit arrangement for the same and a method of operating such devices.

It is another object of our invention to provide new and improved low pressure positive column discharge devices, such as fluorescent lamps and generators of ultraviolet radiation, which afford greater efficiencies in operation than that afforded by the prior art devices.

It is a further object of our invention to provide new and improved electric discharge devices which permit the production of the same or greater amounts of radiation by using less power, or which produce the same amount of radiation in smaller structures.

It is a still further object of our invention to provide new and improved fluorescent lamps which are of smaller physical size for the same electrical specifications and radiation output, and which make possible great savings in manufacturing cost thereby resulting in a lower selling price of such lamps incident to the economy resulting from smaller envelope size and smaller amounts of fluorescent material needed.

In the fluorescent lamps and ultra-violet generating lamps, such as germicidal lamps, commercially available at the time of filing this application, argon is generally used as a filling gas with mercury in order to facilitate

starting of the devices and to permit the devices to operate with a cathode voltage drop which is below the disintegration voltage. For example, in many of these prior art devices the nominal argon filling gas pressure is about 3.5 mms. If the pressure is reduced much below this value, the life of such devices is shortened because of an increase in cathode voltage drop during starting at such low gas pressures. On the other hand, if the argon pressure is increased above the 3.5 mm. value, there is a decrease in efficiency, such decrease in efficiency for a device of a given physical size being due to an increased voltage drop in the device which accompanies the increase in pressure.

For convenience in describing our invention and its advantages over the prior art lamps reference is made to the now conventional 40 watt fluorescent lamp having thermionic electrodes and which has an operating voltage of about 108 volts and an operating current of about 0.4 ampere. It is to be understood that this reference to a particular lamp does not limit the scope of application of our invention, but is employed merely as a convenient comparison basis. The manner in which the power input to a low pressure positive column type electric discharge device is consumed may be considered by referring to a low pressure positive column fluorescent lamp such as the prior art 40 watt fluorescent lamp, having an envelope length of 48 inches and a diameter of  $1\frac{1}{2}$  inches, and in which the ionizable medium comprises mercury and argon at a pressure of 3.5 mms. of mercury. Analysis shows that the 40 watts input is consumed as follows :

(1) The energy loss at the electrodes which, in the lamp under consideration, is about 6 watts.

(2) Losses due to ion and electron recombination on the wall of the enclosing envelope and which is a continuously replenishing process. This is the energy

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consumption which is essential to permit the current to pass through the discharge column, and in the 40 watt lamp amounts to slightly less than about 1 watt. The energy of the electrons in the discharge adjusts itself to a value which is just sufficient to compensate for the ion and electron losses to the envelope wall.

- 5 (3) Approximately 20 per cent of the 40 watts supplied, that is 8 watts, is lost in the positive column of the ionizable medium comprising mercury and the argon. This loss may generally be referred to as the gas losses.

- 15 When equilibrium of wall losses and ion generation is reached, the energy of the greater proportion of the electrons is below the minimum excitation and ionizing potential of the filling gas. These electrons however are able to excite the mercury vapour producing the following radiation:

- (4) 22 watts of 2537 Angstrom unit radiation, which excites the fluorescent material to produce the visible radiation.
- 25 (5) 2 watts of 1847 Angstrom unit radiation.
- (6) about 1 watt of visible radiation directly.

- In accordance with our invention we have found that radical improvements may be made in low pressure positive column electric discharge devices using as the ionizable medium, which supports the arc discharge, mercury and an inert gas consisting substantially of krypton or xenon, or a mixture thereof, and that the maximum or optimum quantity of radiation can be obtained by correlating the wall loading of the enclosing envelope to the inert starting gas pressure.
- 40 In this manner, the operating temperature of the device and the ionizable medium pressure are controlled to obtain operation of the device within a region of the radiation output-envelope temperature characteristic in which the radiation output does not vary more than 5 per cent with respect to the maximum value of the latter characteristic.

- More specifically, we have found that in low pressure positive column electric discharge devices having given electrical specifications with respect to power input, that is, voltage and current supplied to the device terminals, we may obtain in a device having the same or given envelope diameter and which is 50 per cent longer, substantially the same amount of radiation per unit length, and therefore obtain a material increase in efficiency. Alternatively we may construct a low pressure electric discharge device, having specified voltage and current consumption, of the same length but with a smaller diameter than that of a conventional device and obtain the same amount of radiation therefrom, thereby making it

possible to obtain a device of the same or greater radiation output at lower cost due to the reduction in bulb size or diameter. Thirdly, we may construct low pressure positive column electric discharge devices to have specified voltage and current ratings and wherein the lamp affords greater efficiency.

While it has already been suggested before to use electric discharge devices with a krypton or xenon filling the results obtained with such gas fillings have not been satisfactory, and the desirable operating conditions stated above are only obtained by correlating the pressure of such a gas filling to the wall loading of the envelope.

Accordingly, the invention resides in a low pressure positive column electric discharge device of the kind comprising in an envelope electrodes and an ionizable medium including an inert gas filling which consists substantially of krypton or xenon or a mixture of the same, wherein the starting pressure of the inert gas does not exceed 12 millimetres of mercury and the wall loading of the envelope surface is within the range of 7 to 21 milliwatts per square centimetre.

90 For a better understanding of our invention reference may be had to the following description taken in connection with the accompanying drawing. Fig. 1 of the accompanying drawing illustrates an exemplary embodiment of our invention as applied to a low pressure positive column fluorescent lamp. Fig. 2 is a set of curves showing the radiation output-lamp life characteristic for a fluorescent lamp constructed in accordance with our invention for different pressures of krypton employed as the filling gas. Fig. 3 is a radiation output-bulb or envelope temperature characteristic for such a lamp; and Fig. 4 is a radiation output-current characteristic showing the relationship between radiation or lumens output with respect to current for different constant values of mercury vapour pressure.

110 Fig. 1 illustrates a low pressure positive column fluorescent lamp, which is one type of device to which our invention may be applied. The lamp comprises an enclosing envelope 1, constructed of glass, quartz or other material pervious to the radiation to be emitted, and having positioned therein spaced electrodes 2 and 3, which may be of the thermionic or filamentary type, although our invention is not limited to this type of electrode, and may be used with electrode constructions of any type or configuration whether operated as hot or cold electrodes, and whether activated or not. The electrodes 2 and 3 illustrated may be of the filamentary type constructed of a refractory metal, such as tungsten, and which may be provided with activating

coatings of an alkaline earth metal, such as oxides or carbonates thereof. The electrodes 2 and 3 may be supported by lead-in wires 4, 5 and 6, 7, respectively, which also serve as electrical connections to the electrodes from externally accessible contact pins 10, 11 and 12, 13 which are supported by bases 8 and 9. The use of two pins at each end of the lamp for connection to the electrodes is, of course optional, the form of such structure depending upon the nature of the electrodes employed.

Within the envelope 1 we employ as an ionizable medium a quantity of mercury, indicated by the globule 14 and a filling or starting gas, which is substantially either krypton or xenon, or a mixture thereof. The quantity of mercury used may be somewhat in excess of that required during normal operation of the lamp; and the pressure of the mercury vapour during operation may range from about 3 to 20 microns, having a cold pressure of about 1 to 3 microns. The stated operating range of mercury vapour pressure corresponds approximately to the preferred envelope temperature operating range of 30° C. to 50° C. indicated in Fig. 3.

By correlating the pressure of the krypton or xenon, or mixtures of these gases, to be not greater than about 12 mms. of mercury, with respect to the wall loading to lie within the range from 7 to 21 milliwatts per square centimetre, inclusive, we obtain improvements and increases in the quantity of radiation, and also obtain very substantial improvements in the efficiency of production of such radiation, whether it be ultraviolet radiation or visible radiation. Any suitable voltage or current controlling means, such as a variable-voltage leakage reactance auto-transformer may be connected between an alternating current supply circuit and the lamp terminals to control the current supplied to the lamp.

In the operation of a fluorescent lamp, it will be appreciated that the mercury supporting the arc discharge serves primarily as the source of 2537 Angstrom unit line radiation which in turn excites a phosphor or fluorescent material 15 which is preferably placed on the interior surface of the envelope and which converts the invisible ultra-violet radiation (2537 Angstrom unit radiation) into visible radiation.

There have been at least three previous attempts to use krypton as a filling gas in the place of argon in low pressure discharge lamps, ultraviolet generators and germicidal lamps, but these have been unsuccessful or impractical. These prior attempts have not been productive because in each case an attempt was made to produce a device of a given physical size and as of the same

wattage as with argon. The radiation 65 output of a low pressure discharge device, or the light output of a low pressure fluorescent lamp, does not increase linearly with current but tends toward a saturation value as the current is increased. If one attempts to equal the wattage of a lamp using argon as the starting gas by merely increasing the current, the gain in light (lumens) is insignificant due to the non-linear relation between light and current.

To compare lamps or discharge devices it is possible to use any one of four factors as the basis, which factors may be defined as: equal wattage, equal radiation or lumens output, equal currents and equal dimensions. Irrespective of which basis is used, devices constructed in accordance with our invention afford the above-described advantages.

The term "wall loading" as used herein means the energy or power dissipated per unit area, such as milliwatts per square centimetre, of the envelope area, not including the losses at the electrodes. The energy input to the positive column of a low pressure positive column electric discharge device is considered as the energy or power input to the lamp terminals minus the losses at the electrodes. The "wall loading" is the difference between the above defined energy input to the positive column minus the energy radiated out of or from the lamp, all divided by the surface area of that portion of the lamp surrounding the positive column which in most instances is substantially the entire tubular envelope area. For example, in the case of a fluorescent lamp of the low pressure positive column type the energy radiated is the wattage value of the visible radiation or light emitted by the lamp. In the case of an ultraviolet generating lamp, such as a germicidal lamp, which produces 2537 Angstrom unit line radiation, the energy radiated from such a lamp is of course the number of watts of 2537 Angstrom unit radiation. In this manner, the term "wall loading" takes into consideration all conversion losses, which latter term does not include electrode losses.

By incorporating the teachings of our invention in electric discharge devices, such as fluorescent lamps, we accomplish increases in lumen output, increased efficiency, or lower lamp cost and higher efficiency for the same lumen output. In order to show the manner in which these advantages are obtained by constructing lamps in accordance with our invention, we will consider three cases:

- (1) The construction of a lamp having specified current and voltage consumption.
- (2) Construction of a lamp having a given length and specified voltage and current consumption.

(3) Construction of a lamp having a specified definite size, i.e., length and diameter.

Where it is desired to construct a lamp 5 having a specified current, the lumens output for this current may be determined from characteristics such as that generally shown in Fig. 4 where constant mercury pressure curves show the relationship between the 10 relative lumens output and the current. For operation within the region to the left of the maximum value of the curve shown in Fig. 3, curves A and B of Fig. 4 represent the current lumen relation at particular 15 lower and higher mercury vapour pressures respectively. For operation to the right of the maximum value in Fig. 3, the mercury vapour pressure relation is reversed, that is, curve A of Fig. 4 represents the conditions 20 at higher value constant mercury vapour pressure. By using a wall loading of the envelope, incident to the losses in the positive column as above defined, to have a value lying within the range from 7 to 21 25 milliwatts per square cm., inclusive, and by using a gas filling of krypton or xenon, or mixtures thereof, having a pressure not greater than 12 mms., we effect operation of the lamp within the region of the maximum 30 value of the characteristic of Fig. 3, or within a region thereof between 30° C. and 50° C. envelope temperature in which the lumen output does not vary more than 5 per cent of the maximum value, for an 35 ambient temperature of the atmosphere surrounding the envelope of about 25° C. When constructed in this manner to have these features, by increasing the envelope length to a value to obtain a required voltage, 40 we find that there is provided a lamp having a length 50 per cent greater than the prior art lamps, and which has the same voltage and current input or consumption, and which provides about the same number of 45 lumens per unit length or foot, and which furthermore provides increases in luminous efficiency ranging to about 15 per cent or more.

In those instances where it is desired to 50 employ our invention in a lamp having a fixed length and given voltage and current ratings the same features as to gas filling pressure and wall loading may be incorporated in the lamp, the envelope area or diameter 55 being determined to bring the voltage to the given value and the wall loading within the stated range from 7 to 21 milliwatts per square cm., inclusive. When krypton or xenon or mixtures thereof at the stated 60 pressures are used the envelope diameter is decreased as compared with the prior art lamps, however the amount of light or the total lumens is at least equal to that of the prior art lamps, and offering the further

advantage of at least equal or greater 65 efficiency and reduced lamp cost due to substantial reductions in lamp envelope area and diameter and the amount of fluorescent material needed.

Lastly, by incorporating the feature of 70 envelope wall loading and gas pressures of krypton or xenon, or mixtures thereof, we make it possible to construct lamps having a given voltage and current rating, and in which there is obtained the above stated 75 improvements in efficiency and lamp economy.

When krypton is used as the gas filling, and where the krypton gas filling pressure is preferably within the range from 1 to 6 mms. 80 of mercury, inclusive, the lamps so constructed show good maintenance of light output, as evidenced by the curves shown in Fig. 2, for the different indicated values of pressure. These curves are not to be 85 construed as indicating a limitation on the pressure range intended and beneficial, but to indicate merely the direction of variation due to changes in pressure.

The above described advantages incident 90 to the use of krypton or xenon do not sacrifice lamp performance. Even though it is possible to use lower pressures of krypton or xenon, compared with argon pressures, equal cathode protection is 95 obtained due to the higher atomic weights of krypton and xenon. Because it is possible to use krypton pressures as low as 2 mms., and lower, as contrasted with 3.5 mms. of argon, the use of smaller quantities of 100 krypton assists in offsetting the present higher costs of krypton as compared with argon.

We have observed from lamps constructed as described that there are no bands (end 105 discolouration) in any lamps using krypton. Although the starting voltage of krypton lamps is somewhat higher than that for argon lamps, this feature is not a substantial disadvantage particularly where a starting 110 device is used. On the other hand, the lower operating voltage of krypton lamps gives them a distinct advantage in those instances where the open circuit voltage of the associated ballasts is important. 115

The inclusion of the above described principles in low pressure positive column fluorescent lamps uniformly effects a reduction in the amount of gas losses of the positive column, and of course results in 120 improved efficiency and in substantial increases in the amount of visible radiation obtainable. The increase in the amount of visible radiation obtained is, of course, due to the increased efficiency in the production 125 of the 2537 Angstrom unit line radiation which excites the phosphor. For instance, in one type of argon-mercury lamp investi-

gated where the gas losses in the positive column were 8 watts, by the use of krypton at a pressure of about 2 mms., the gas losses have been reduced to 2 watts. As another example, in a 100 watt argon-mercury fluorescent lamp, by incorporating the above described principles, the same amount of light, that is visible radiation, is obtained requiring only 85 watts input to the lamp, resulting in a very substantial improvement in efficiency.

HAVING NOW particularly described and ascertained the nature of our said invention and in what manner the same is to be performed we declare that what we claim is:—

1. A low pressure positive column electric discharge device of the kind comprising in an envelope electrodes and an ionizable medium including an inert gas filling which consists substantially of krypton or xenon or a mixture of the same, wherein the starting pressure of the inert gas does not exceed 12 millimetres of mercury and the wall loading of the envelope surface is within the range of 7 to 21 milliwatts per square centimetre.

2. A device as claimed in claim 1 wherein the gas pressure is one millimetre or higher and the operating temperature of the envelope is between 30 and 50° C.

3. A device as claimed in claim 1 or 2 wherein the gas filling comprises substantially krypton and the gas pressure is

between one and six millimetres of mercury.

4. A circuit arrangement including an electric discharge device as claimed in any of the preceding claims including a means, such as a variable-voltage leakage reactance autotransformer, for controlling the input current so as to obtain the desirable wall loading.

5. A device as claimed in any of the claims 1-3 operating under conditions wherein the power input is maintained to effect operation of the device within the region of the radiation output-envelope temperature characteristic in which the output does not vary more than 5% with respect to the maximum value of said characteristic.

6. A low pressure positive column electric discharge device substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

7. A circuit arrangement including a low pressure positive column electric discharge device substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

8. A low pressure positive column electric discharge device operating under conditions substantially as hereinbefore described with reference to the accompanying drawing.

Dated this 3rd day of January, 1949.

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This Drawing is a reproduction of the Original on a reduced scale

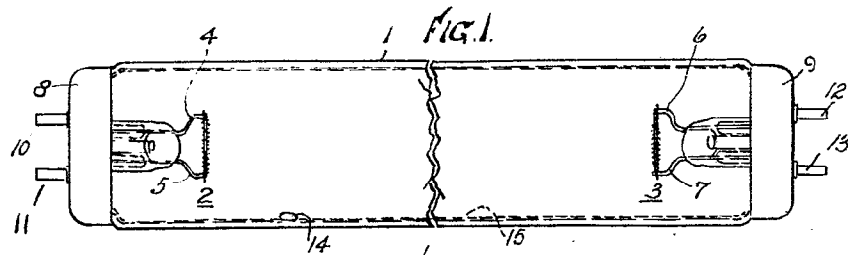


FIG. 2

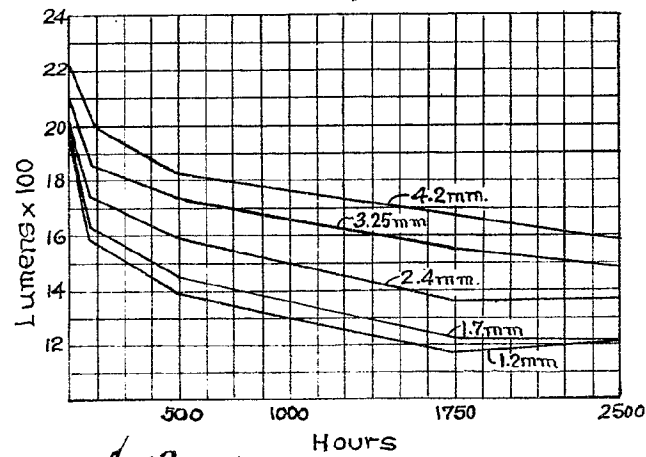


FIG. 3

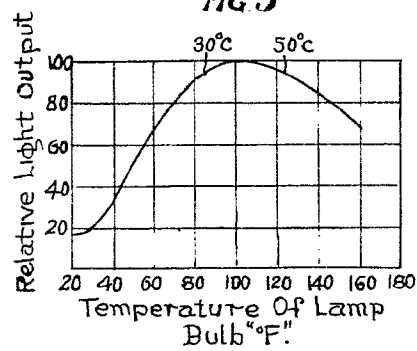


FIG. 4

